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Traps in spinal MR imaging

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KEYWORDS

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Abstract There are many traps in spinal MRI in part related to the technique but also due to the existence of anatomical variations, lesions which are difficult to confirm because of non-specific signs, and sometimes rare conditions.

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As when imaging other spinal structures (the spinal cord, roots, meninges), there are many variants in imaging vertebral structures, which are linked either to a particular anatomical configuration or to a parameter specific to the imaging technique used. Depending on the type of imaging, modification of the vertebral structure may or may not be visible. The same is true of morphological changes.

All these variations can produce just as many trap images that we need to recognize, either from our own radio-anatomical knowledge or by performing an additional imaging examination.

Spinal variations in standard X-ray images

The frequent use of slice imaging techniques relegates standard X-ray images to the background and can result in a reduction in the analytical relevance of these images, poorer knowledge of unusual images and in the end, disrupt their interpretation. The normal spinal variants have been listed for many years and presented in various works, the best known of which are Keats' Atlas [1] and the work of Koehler and Zimmer [2].

All spinal segments may have anatomical variations of the bodies and arches.

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The cervical spine

The cervical spine is the site of many anatomical variants which the most frequent are:

- images of indentations: the most common are more or less pronounced paramedian indentations in the lateral masses of the atlas and axis (medial paraglenoid groove);
- images of canals on the body of C2 (insertion of the lateral masses: Harris's ring), on the lateral masses of the atlas or axis (passage of the vertebral artery) or above the posterior arch of the atlas (complete or incomplete ponticulus posticus);
- opacities: projection of the transverse process of the atlas onto the odontoid viewed in profile; calcified vestigial disc at the base of the odontoid;
- dehiscence of the posterior arch of the atlas (absence of the spinolaminar line and hypertrophy of the anterior arch), of the anterior arch or failure of the two hemi-arches to fuse (split atlas);
- addition images: inferior ossification nucleus of the anterior arch of the atlas or the superior pole of the odontoid which must be differentiated from traumatic avulsion;
- hypertrophy of the anterior tubercle of the transverse process of C6 and sometimes C5 extending beyond the anterior vertebral wall, a projection onto the body of an exaggerated uncovertebral disc arthrosis viewed in profile, opacity of the body through the projection of a cervical rib, failure of fusion of the anterior vertebral rim;
- abnormalities of the articular processes (hypertrophy, hypotrophy or absence of an articular process modifying the appearance of the foramina on oblique incidences, dehiscence of the posterior arch, pedicle or pedicle and articular agenesis).

The thoraco-lumbar spine [3,4]

The thoraco-lumbar spine is also the site of many anatomical variants which we need to be aware of and which are found in both the vertebral body and the posterior arch.

Anterior vertebral scalloping of one or more vertebrae does not necessarily indicate the presence of a prevertebral expansive process such as an aortic aneurysm or adenopathies.

The shape and dimensions of the pedicles in a PA projection are very variable. Although the pedicles are usually oval, in the long vertical axis, they are sometimes rounded with a thin cortex or may have concave lateral borders. This physiological thinness of the pedicles, which is responsible for an increase in the interpedicular distance, is not necessarily synonymous with an intramedullary expansive process. Moreover, vertebral rotation causes unilateral thinning of the pedicle, the affected pedicle being in the concavity of the curvature.

The presence of a vascular channel in the vertebral body is not unusual. This cleft, the edges of which are clearly limited by cortical bone, can be anterior, posterior or complete; it is median, equidistant from the superior and inferior vertebral endplates.

The persistence of unfused ossification nuclei must be differentiated from bone avulsion, especially in a traumatic context. The site of these nuclei is variable and may be



Figure 1. Dehiscence of the posterior arch at T11, T12 and L1.

the vertebral rim, the transverse process or the articular process.

Dehiscence of a posterior arch (Fig. 1) and the presence of disc calcification may be variants of the normal.

Neighbouring bone structures superimposed on the spine can be misleading: PA projection of the manubrium sterni simulating vertebral compression by the Mach effect, and pseudo-spondylolisthesis, with the appearance of an isthmic defect, are sometimes visible in L2 and L3 (superposition of the transverse process) or L5 (projection of the sacral ala). These isthmic 'pseudo-defects' disappear on an oblique incidence image, which means they can be differentiated from true spondylolysis.

A variable number of definite linear opacities, close and parallel to the vertebral endplates, are growth lines, as in long bone metaphyses.

Two concavities present on the lower endplate of certain vertebrae, particularly L4 and L5, are known as Cupid's bow; opposite these impressions, the hyaline cartilage normally overlying the vertebral endplates will be absent, and the cortex will be thickened. No disc abnormalities, particularly nuclear, have been described.

Lumbosacral joint abnormalities are by far the most common variations. They are minimal malformations. Hemisacralisation or sacralisation of L5 is apparent because of unilaterally or bilaterally enlarged transverse processes and a neo-articulation with the sacral ala. It is not always easy to differentiate between sacralisation of L5 and lumbarisation of S1, without resorting to counting the different vertebrae from the thoracic or even cervical level.

Anatomical variations often affect vertebral morphology, and if there is any doubt an unusual image should be clarified by performing a CT examination to confirm normality.

Spinal variations in CT scans

Variants connected with the technique

Current multiplanar reconstruction tools help avoid the appearance of frequent images on axial slices produced in incremental mode.

Disc pseudo-protrusion

Rotation is responsible for a disc appearing to protrude laterally into the intervertebral foramen; the rotation can be corrected secondarily during image reconstruction. This image must be differentiated from a foraminal disc hernia.

Pseudo-calcification of the ligamentum flavum

The inner edge of the ligamentum flavum sometimes has a border of the density of bone, which must not be confused with ligament calcification. This pseudo-bone limit, due to a partial volume effect, is none other than the laminar border found on the immediately subjacent slice (pedicular-laminar slice). There can be a similar image in the facet joints which must be differentiated from an osteoarthritic process.

The facet beam hardening artefact

The facet beam hardening artefact is seen as hypodensity in the posterior segment of the dural sleeve simulating the existence of a posterior disc protrusion.

Anatomical variations [3,5]

Vascular clefts

Median and axial canals are often visualised in vertebral bodies (Fig. 2). Their appearance varies and may be of V or Y images or posterior cortical fenestration with a bone septum. These channels, through which the basivertebral veins pass, may simulate fracture of the vertebral body.

Posterior spur of the vertebral body

This median spur on the posterior border of the vertebral body is a tubercle at the point where the vertebral vessels emerge.



Figure 2. Axial CT image: vascular clefts.

Ossification of the superior insertion of the ligamentum flavum

An insertion crest on the anterior surface of the lamina is a common anatomical occurrence which is much more rarely seen on CT scans. It occurs most frequently at T9-T10, diminishing progressively towards T1 and L5.

A foraminal spur

An often bilateral bone spur, originating in the region of the isthmus or pedicle, can occupy the intervertebral foramen. Located behind the nervous components, this bony process could correspond to ossification of the ligamentum flavum. It is asymptomatic and must be differentiated from an osteophyte, a calcified disc fragment or a bone fragment of traumatic origin.

Intra-spongy hernias

The CT appearance suggests this variation, appearing as a variably sized, rounded, hypodense area with a dense border. The site of these hernias in the body is close to the intervertebral space. Intra-spongy hernias can be anterior, median or posterior (Fig. 3).

Accessory ossicles

Accessory ossicles arise from unfused secondary ossification nuclei. They are found at the summit of the various vertebral processes. Seen on axial or coronal slices, they are clearly delimited by peripheral cortical bone. The main differential diagnosis is traumatic bone avulsion.

Failure of fusion of the anterior vertebral rim

The vertebral rim, which normally fuses at about 15 years of age, can remain separate. The CT appearance is identical to that of a retromarginal disc hernia.

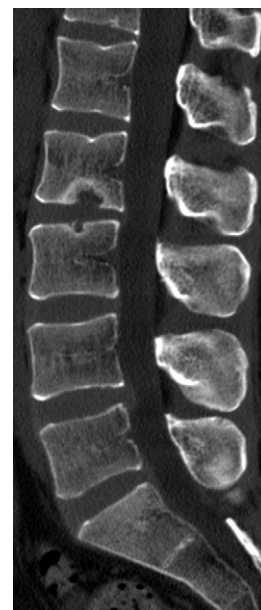


Figure 3. Sagittal CT image: intra-spongy hernia at L2, vascular clefts.



Figure 4. CT myelogram, axial slice: remains of a synchondrosis.

Remains of synchondroses

Neurocentral synchondroses may sometimes persist in adults. Situated at the posterolateral angle of the vertebral body, neurocentral synchondroses extend vertically through the vertebral body. They progressively ossify to disappear in the lumbar region at about 6 years of age. Persistence of a synchondrosis leads to dehiscence. More often than not, there is a band of bone condensation (Fig. 4).

Pedicular or retro-somatic dehiscence occurs through the same mechanism; it is very rare as are cases of retro-isthmic dehiscence. Cases of paraspinal or spinal dehiscence (spina bifida) are much more frequent.

The zygapophyseal joint space

The presence of an air-like, hypodense image in posterior zygapophyseal joints is a common phenomenon. The articular facets are normal, without signs of degenerative change. This image is much more common in the context of facet joint osteoarthritis. This well-known 'empty joint' phenomenon results from traction on the posterior vertebral joints during movement of the spine.

The lumbosacral vertebral canals

Well-defined orifices of varying size are often present on both sides of the lumbar canal at L5 or S1. Located at the base of the superior articular process and the base of the transverse process, this orifice may correspond to the axial section of a tunnel resulting from calcification of the mamillo-accessory ligament. This ligament stretches between the mamillary process, located at the base of the superior articular process, and the accessory process, located at the base of the transverse process. According to some authors, this channel forms a passage for nerve structures, whereas for others, channels with a diameter less than 3 mm are occupied by veins.

Conjoint nerve roots

The conjoint emergence of two roots at the same level appears on a CT scan as:

- an anomaly of the dural sac – that is deformed, oval, displaced and stretched laterally towards the recess, which is occupied by a structure the density of which is similar

to that of the intervertebral disc, raising the suspicion of a migrated or excluded herniated disc, associated with;

- a bone deformation of the lateral recess, which is enlarged on the side of the anomaly. The diagnostic doubt can be resolved by conducting radiculography or MRI to show the emergence anomaly.

Meningeal cysts

There is a high frequency of nerve root meningeal ectasia, the volume of which is also very variable. Depending on their volume and position, cysts can leave an imprint on surrounding bony structures: enlargement of a lateral recess occupied by a large root, an imprint on the lamina. MRI or radiculography will confirm the diagnosis where there is doubt.

Transitional anomalies are at the limit of morphological variants since they correspond to minor malformations. The appearance in an axial slice can be completely superimposed on the appearance described in conventional radiography. Very often, they involve hypertrophy of a transverse process and the creation of a new articulation with the sacral ala opposite.

MRI spinal variants [5–11]

The most common diagnostic traps in magnetic resonance imaging are essentially anomalies of normal or pathological signals and sometimes, atypical pathological appearances. It is therefore useful to recall the normal MR imaging appearance of the vertebra/disc complex according to the sequence used.

MRI anatomical overview

The vertebral body

On T1-weighted sequences, the vertebral body, composed of haematopoietic marrow, appears with a high signal and intensity intermediate between the paravertebral fat signal and the signal from the muscle structures.

On T2-weighted sequences, the medullary signal decreases.

The body signal reflects the composition of the spongy bone and more particularly, the relationship between the three medullary components: the haematopoietic or red marrow, the fatty or yellow marrow and the trabecular bone. Normal distribution of the marrow and thus its signal varies with age and other factors. After maturation, normal proportional physiological conversion occurs of the active haematopoietic marrow into inactive haematopoietic marrow. Four appearances of physiological conversion with age of the active haematopoietic marrow into inactive yellow marrow have been described in T1-weighting.

The yellow marrow signal changes like the subcutaneous fat signal in T1 and T2-weighting. Its intensity is low or intermediate in T2-weighting with fat saturation, while a STIR sequence suppresses the yellow marrow signal. The red marrow appears with an intermediate signal in T1-weighted images and a heterogeneous appearance is common. With T2-weighting, the intermediate signal intensity of the red marrow is often difficult to distinguish from that of the

yellow marrow. STIR sequences or with fat saturation are very useful in this case: the red marrow signal is higher than that of the saturated yellow marrow.

In T1-weighting, the red marrow signal is higher than the signal from normal muscle or the intervertebral disc. This comparison means that pathological changes can be seen.

The coexistence of red and yellow parts in the vertebral medulla explains the possible heterogeneous appearance with sometimes concentration focused on the red or yellow parts that can suggest the existence of a pathological process.

Venous drainage of the vertebral endplates is sometimes seen as a hyperintense line parallel to the endplate, the signal from which is enhanced by gadolinium injection. This image differs from the chemical shift artefact due to the fact that it persists despite a change of phase encoding direction.

With T1-weighting, the intensity of the signal from the basivertebral vein in its channel in the middle part of the vertebral body is high due to the perivenous fat and/or slow intravenous flow. It emerges from the vertebral body via a cortical foramen in the posterior vertebral wall apparent in sagittal and axial slices (Fig. 5). A cortical spur sometimes dominates the point of emergence of the vein from the body. The signal intensity from the basivertebral vein in T2-weighted images is also high.

An imprint of the nucleus is frequently present on the vertebral endplates at the union of the posterior third with the anterior two-thirds. Sometimes, there is an intra-spongy hernia, which is most often anterior retro-marginal, constituting an anatomical variation even though there are no associated signs, which could suggest vertebral osteochondrosis.

Posterior vertebral joints

Articular facets and the joint space are identified on sagittal and, above all, on axial slices. The differentiation between cortical and spongy bone is better seen on proton density SE sequences than with T1 or T2-weighting. Spongy bone has a homogeneous intermediate signal identical to the signal from the body while cortical bone is hypointense.



Figure 5. MRI: sagittal T1-weighted image: vascular clefts.

Hyaline cartilage covering the articular facets is visible in the sagittal and axial planes. In the sagittal plane, the reference slice passes through the median part of the joint, the middle of the pedicle and isthmus. The axial plane is best for examining the facets and joint space. The signal from the cartilage is between the signal from the fat and from the bone marrow. The cartilage can be identified on SE images but above all with gradient echo sequences. The thickness of the cartilage is not adequately measured due to partial volume artefacts and the possibility of a chemical shift artefact.

The joint capsule is not visible: its anterior-superior segment merges with the ligamentum flavum and the inferior-posterior merges with the bone.

The posterior vertebral joints can take on many different appearances in MR imaging, because of the possibility of expansion of the fatty and synovial fringes beyond the joint space. Extension of intra-articular structures beyond the joint cavity results in signal anomalies on either side of the joint space, under or within the ligamentum flavum.

The intervertebral disc

The intervertebral disc consists of three very distinct structures: the cartilaginous plates, the annulus and the nucleus.

The cartilage that covers the vertebral endplates is indistinguishable from the cortical bone and the nucleus.

The signal from the annulus and the nucleus in T1 and T2-weighted SE sequences as well as with gradient echo reflects the water content and the distribution of collagen fibres in these two structures.

The signal from the intervertebral disc is of intermediate intensity with T1-weighted sequences and is hyperintense on T2-weighted images. There is no difference in signal between the nucleus and the deep layers of the annulus: with either weighting, these two structures cannot be distinguished. In T1-weighted images, hypointensity is more pronounced in the anterior segment of the intervertebral disc indicating the eccentric position of the nucleus and, as a consequence, progressive reduction in the water content of the disc from the centre towards the periphery. This transition is pronounced in young subjects and disappears in older subjects. In both its anterior and posterior segments, the external layer of fibres of the annulus appears as a hypointense band at the periphery of the disc with T1 and T2-weighting. Sharpey's hypointense fibres are indissociable from the low intensity of the posterior longitudinal ligament. The external annular fibres, inserted in the cartilage of the vertebral endplate, and Sharpey's fibres, inserted in the vertebral rim, are sometimes clearly individualised in the posterior segment of the disc space. Variations in the state of disc hydration during a nycthemeron do not result in noticeable modification in the disc signal.

In T2-weighting, a horizontal, hypointense band (central nuclear cleft) occurs at the centre of the disc in more than 90% of patients over the age of 30. This line corresponds to degenerative fibrosis of the gelatinous matrix along the line of separation of the sclerotomes of the notochord. Sometimes, a remnant of the notochord produces an anterior high intensity signal.

How to assess the vertebral signal (VS): compare the signal from the vertebral body with the disc (DS) and/or muscle (MS) signal.

- Normal VS > DS or MS
- Pathological VS < DS

Morphological variations of bony structures

Morphological variations of bony structures consist of:

- abnormalities of formation (hemivertebrae) or segmentation (block vertebrae);
- fusion abnormalities: odontoid bone, butterfly vertebrae, spina bifida, limbus vertebra, which can simulate a marginal fracture in an X-ray or CT scan following recent trauma. MRI can provide the diagnosis when there is no medullary oedema;
- intra-spongy hernia or Schmorl hernia: frequent intra-somatic disc hernia at the thoraco-lumbar junction. The signal is hyperintense in T2-weighted images within the vertebral body with marginal sclerosis which is hypointense with T1 and T2-weighting;
- lumbosacral transitional anomalies;
- sequelae of vertebral osteochondrosis.

Variations in bone signal

Medullary signal variations, depending on age, various treatments (chemotherapy, radiotherapy).

Islets of focal hyperplasia in the red marrow: hypointense with T1-weighting, hyperintense with STIR or T2-weighting with fat saturation (Fig. 6).

Persistent notochord: persistence of notochord cells and non-ossified embryonic cartilage within the vertebral body usually in the lumbar region and affecting one or more vertebral bodies. This cartilage structure has a low intensity signal with T1-weighting, high intensity relative to the signal from the vertebral medulla with T2-weighting and peripheral sclerosis with low intensity with T1 and T2-weighting. Injection of a contrast agent causes a high intensity signal.

Focalised fatty deposits adjacent to degenerative bone lesions (osteophytes) are frequent at the thoraco-lumbar junction (Fig. 7) and must be differentiated from early



Figure 7. MRI: sagittal T1-weighted image. Vertebral lesion in a context of SAPHO.

spondyloarthropathy lesions [12,13] (Fig. 8) or early or subsequent spondylodiscitis.

Quiescent vertebral angiomas can be considered as structures at the limit of normality.

The presence of signal modification (T1-weighted hypointensity, T2-weighted hyperintensity) from the articular complexes indicates the existence of mechanical damage and will guide an injection where there is pain [14,15].

Disc modifications

Disc protrusions visualised by MRI in the thoracic region (T1 and T2-weighted hypointensity) are frequently calcified hernias: a CT scan provides the evidence.

Disc calcification can show variably as hypointensity or hyperintensity on T1-weighted slices [16,17].

Isolated nodular hyperintensity with T2-weighting (hyperintensity zone HIZ) within a disc protrusion indicates disc degeneration.

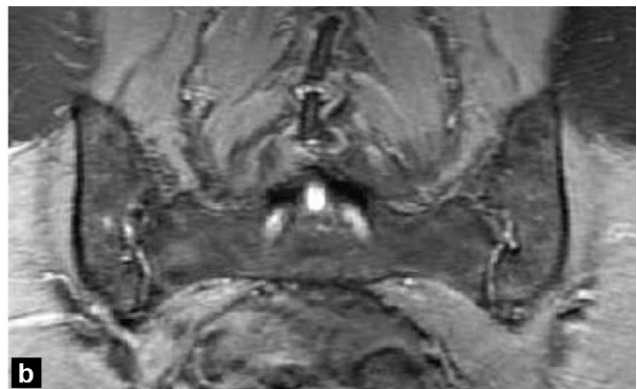
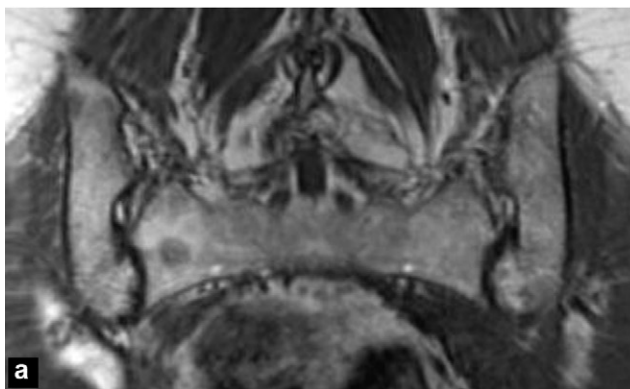


Figure 6. MRI of the sacrum. a: coronal T1-weighted image; b: coronal proton density image with fat saturation. Visualisation of a zone of focal red marrow hyperplasia (arrow).



Figure 8. MRI: sagittal T2-weighted image. Spondylodiscitis after 3 months of treatment.

Conclusion

The diagnostic problem posed by the variations in vertebral morphology, which are just as many traps in standard X-rays, can be solved by learning to recognise them or by performing a CT examination using multiplanar reconstruction.

The complementarity between MRI and CT can also remove doubts concerning certain images. Nonetheless, there are some MRI signal abnormalities for which no rational explanation can be found, despite the sequences being complementary, and which are arbitrarily considered as normal images if there are no clinical and laboratory changes. Vertebral biopsies with a histopathological examination should be reserved for doubtful cases in a clinical context which is compatible with the presence of a vertebral lesion.

Know the examination technique well (its properties and limits).

Compare clinical and imaging data.

Make use of the complementarity between CT and MRI.

If necessary resort to a biopsy if major therapeutic treatment is required.

Know when to stop investigations.

Disclosure of interest

The author declares that he has no conflicts of interest concerning this article.

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